Agricultural Systems xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Impacts of climate variability and food price volatility on household income and food security of farm households in East and West Africa

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ARTICLE INFO

Article history:
Received 28 January 2016
Received in revised form 11 February 2017
Accepted 14 February 2017
Available online xxxx

JEL classification:
Q54
C63
Q12
D12

Keywords:
Climate variability
Food price volatility
Food security
Simulation
Adaptation
Ethiopia
Ghana

ABSTRACT

This paper provides an ex-ante assessment of the impacts of climate and price variability on household income and food security in Ethiopia and Ghana. The study applies an agent-based modelling approach to highlight the role of coping and adaptation strategies under climate and price variability. Our simulation results show that climate and price variability adversely affects income and food security of households in both countries. Self-coping mechanisms are found to be important but insufficient to mitigate the adverse effects of variability, implying the need for policy interventions. Adaptation strategies composed of a portfolio of actions such as the provision of production credit and access to improved seeds are found to be effective in reducing the impacts of climate and price variability in Ethiopia. Similarly, policy interventions aimed at improving the provision of short-term production credit along with the existing irrigation facilities are important in Ghana. Finally, this study highlights the importance of capturing the distributional aspects of adaptation options by highlighting heterogeneous effects of variability and adaptation options.

1. Introduction

Food insecurity remains a critical challenge to the world's poor today. According to recent estimates by the Food and Agriculture organization (FAO) one in nine people in the world and about a quarter of those in Sub-Saharan Africa (SSA) are unable to meet their dietary energy requirements in 2014–2015 (FAO, 2015). Although a range of factors influence food security around the world, local food production and the entitlements that are attached to it play a major role (Parry et al., 2009; Wheeler and von Braun, 2013). Frequent climate shocks affect the access and availability dimensions of food security as most farm households have limited possibilities of externalizing risk through formal insurance mechanisms. This is especially so in SSA where natural resources and rain-fed agriculture that are very sensitive to climate variability form the basis of livelihoods. In fact, using a wide range of methods, previous studies have documented that the impact of climate variability on food security is largely negative for countries most dependent on the agricultural sector (Lobell et al., 2008; Cooper et al., 2008; Deressa et al., 2009; Thornton et al., 2009; Hertel et al., 2010; Di Falco et al., 2011; Claessens et al., 2012; Wheeler and von Braun, 2013; Thiede, 2014; Wossen et al., 2014).

In this paper, we seek to evaluate the impacts of climate and price variability on smallholder productivity as well as the effectiveness of alternative adaptation strategies with a particular focus on Ethiopia and Ghana. Both countries are extremely vulnerable to the impacts of climate variability as agriculture is predominately rain-fed with limited irrigation practice (Di Falco et al., 2011; Arndt et al., 2011; Wossen et al., 2014; Wossen and Berger, 2015).[1] For example, agriculture contributes roughly 43% to GDP, 90% of export earnings and 80% of employment in Ethiopia (MoFEd, 2011). Similarly, in the Upper East Region (UER) of Ghana, agriculture employs about 80% of the economically active population (GSS, 2010). A shift in the distribution, amount or intensity of rainfall will therefore affect food security adversely. In addition to

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[1] For example Mideksa (2010), documented that Ethiopia's GDP will decline by about 10% as a result of climate change. Moreover, as a result of climate change the degree of income inequality is likely to increase by 10%. Similarly, in Ghana previous studies by Wossen et al. (2014) and Wossen and Berger (2015) showed that climate and price variability reduces average household income by 25%.

http://dx.doi.org/10.1016/j.agsy.2017.02.006
0308-521X/

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dependency on climate sensitive livelihoods, pervasive poverty has weakened adaptive capacities of households in both countries. Farmers are therefore highly vulnerable to the impacts of climate variability. Despite the impressive development progress in Ethiopia, poverty appears to have remained broadly pervasive with 29.6% of households still living under the poverty line (CSA, 2012). Similarly, the northern part of Ghana in general and the UER in particular remain poor, with a poverty rate of 73% (GSS, 2010).

Aside from climate variability, increasing price variability has also been a major driver of food insecurity in Ethiopia and Ghana (Headey et al., 2012; Alem and Söderbom, 2012; Ticci, 2011). Wholesale and retail prices of most cereals in Ethiopia reached record levels between October and November 2008. For example, the nominal retail prices almost doubled for wheat, teff, and sorghum, and increased by 150% for maize. The cereal price index (which weighs about 23% of the consumer price index (CPI)) reached a record peak of 290 (December 2006 = 100) in September 2008 (CSA, 2015). The Ghanaian CPI, in which staple food prices contribute a substantial share, exhibited a dramatic increase in 2008 (GSS, 2015). Accordingly, capturing the effect of such price variability in general and of climate induced price variability in particular is crucial. However, existing impact studies that focus on food security have developed into two independent streams, one focusing on climate variability and the other on price variability, giving little attention to the co-variation between climate and prices.

This paper aims to contribute to current knowledge on adaptation to climate variability by considering the following policy relevant questions: What is the expected impact of climate and price variability on household income and food security? What are the adaptation strategies that vulnerable farmers are most likely to adopt? What are the potential distributional effects of the different adaptation strategies on household income and food security? By examining the above policy-relevant research questions, this paper provides a vital input for designing "*best fit*" adaptation plans instead of advocating "*one size fits all*" strategies. Understanding and quantifying the above policy-relevant questions, however, requires taking into account a large number of complex and interrelated factors that can be captured only through integrated household-level models (Berger and Troost, 2014). We therefore employ an Agent-Based Modelling (ABM) approach that is capable of simulating the effects of different adaptation options by capturing the dynamic changes of climate and prices (Wossen and Berger, 2015; Wossen et al., 2014; Schreinemachers and Berger, 2011; Berger and Troost, 2014; Troost and Berger, 2015).

The paper is organized as follows: section 2 presents the conceptual framework employed for measuring the effectiveness of adaptation strategies. Section 3 introduces the data sources, analysis, and methods used as well as the experimental design. Section 4 presents simulation results. Section 5 discusses the findings and their relevance for food security. Section 6 concludes with a list of open questions and an outlook on the next research steps.

2. Conceptual framework

Climate and price variability affects the different dimensions of food security in many ways. In this paper, we focus on the availability and access dimensions of food security. Climate variability affects the availability dimension of food security through its effect on crop and livestock productivity. In addition, climate variability affects relative output and input prices and hence the access dimension of food security indirectly (Wheeler and von Braun, 2013; Hertel et al., 2010). Since climate variability impacts the supply of food products, it will have an effect on food security through what is commonly called "*climate-induced food price variability*". The impact of climate induced food price changes on food security is, however, not always negative. Higher food prices might be a threat to food security as many farm households are net food buyers. Yet, higher food prices may also provide an opportunity for net-seller farmers. The net effect of such climate induced food price variability therefore depends on the market position of households (Hertel et al., 2010; Wossen and Berger, 2015).

In addition, changes in levels and volatility of food prices directly affect food security (availability) through their effects on price expectation formations of food producers. High agricultural commodity prices are typically expected to bring about a positive supply response in which producers allocate more land and other inputs to the agricultural sector and increase investment to improve crop yield (OECD, 2008). However, an increase in price levels, especially in recent periods, has been associated with higher fluctuations (Gilbert and Morgan, 2010). Such price fluctuations introduce risk, with disincentive effects on producers' resource allocation and investment decisions which, in turn, results in sub-optimal agricultural production (Moschini and Hennessy, 2001). In the absence of instruments for managing price risks, fluctuations in food commodity prices imply that agricultural producers make their farming choices based on "expected outcome". Since smallholder farmers tend to be risk-averse, they prefer low-risk and low-return outcomes to more uncertain higher pay-offs. Moreover, large fluctuations in output prices make it difficult for producers to understand the underlying trends in price levels. This has detrimental effects on investments in agriculture, including the adoption of productivity enhancing adaptation measures. Several supply response studies in developing countries indicated that farmers respond to price incentives (Binswanger et al., 1987). Furthermore, a study by Haile et al. (2016)

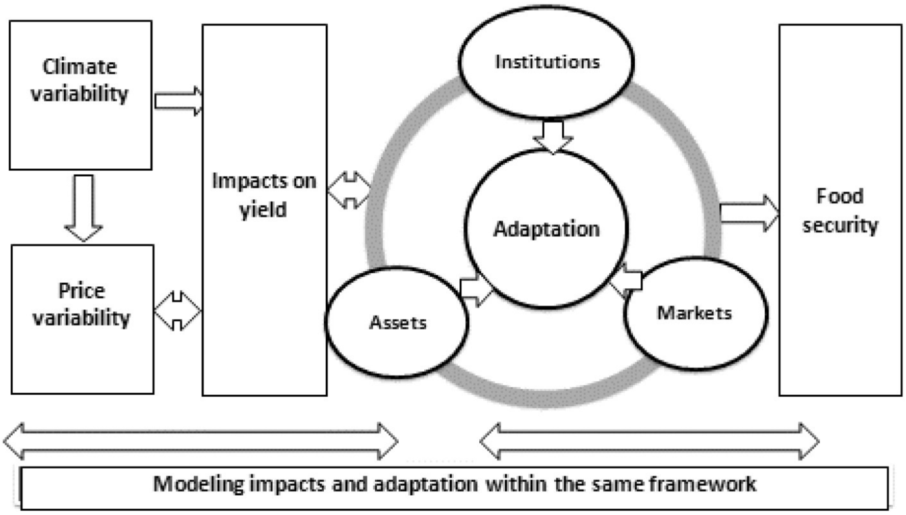

Fig. 1. Conceptual linkages among climate and price variability, adaptation options and food security.

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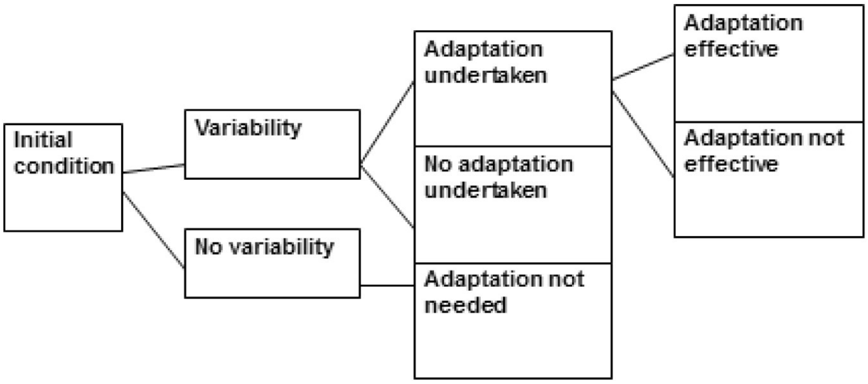

Fig. 2. Simplified decision-making framework for adaptation strategies.

shows that price volatility has weakened the crop production increase that would have been brought as a response to higher price levels. Food price volatility may also increase food insecurity problems since periods of inadequate consumption may not be compensated by periods of excess food consumption (Kalkuhl et al., 2015).

Fig. 1 depicts the link between climate and price variability, adaptation strategies, and food security. Since adaptation strategies towards climate variability entail price changes, we focus on adaptation strategies against climate variability rather than on possible ex-ante responses towards expected price volatility. Fig. 1 underlines the fact that the direct effect of climate variability is transmitted through the productivity (yield) path. This in turn affects the availability dimension of food security directly and the access dimension of food security indirectly. However, climate variability may also affect output and input prices as co-variations may exist between climate variability and local prices. This climate-induced variability in price will certainly affect yield as households adjust their production decisions to changes in relative prices. Moreover, even without productivity changes, price variability will affect food security by altering the purchasing power of households.

As a result, the impacts of climate variability are transmitted not only through yield pathways but also through relative price changes. Considering both factors jointly is therefore important. However, the ultimate impact depends on the level of adaptation - which in turn is affected by policy and institutions, socio-economic settings, and asset endowments. In fact, if adaptation is smooth, impacts can be substantially reduced and adverse effects on food security can be avoided. Therefore, for designing appropriate "*best fit*" policy interventions, capturing adaptation and impacts within the same framework will be very important.

Differences in access to the different components of capital and resource endowments are important in shaping not only the type of adaptation options available to households but also their intensity and effectiveness. Prudent institutions and the policy environment are also important in reducing the impact of climate and price variability and hence in improving food security. On the one hand, the type of policy instruments designed to implement adaptation strategies is to a large extent affected by variability. On the other hand, institutional capacity is crucial in reducing the impact of variability as it impacts research and development for promising adaptation technologies. For example, the strength and ability of institutions determine whether households can have access to short-term credit or off-farm employment options as a coping and adaptation mechanism. However, all adaptation strategies may not necessarily improve food security. Some may even have an adverse impact on the environment and hence exacerbate food insecurity (e.g., natural resource-based adaptation strategies by clearing forests). Fig. 2 illustrates the procedure that this paper follows to evaluate the effectiveness of alternative adaptation options. Given that we consider adaptation options triggered by climate variability, the necessary condition for adopting adaptation practices is experiencing variability. Having experienced variability, households have a choice to either undertake adaptation options or face the full effects of variability (no adaption). The decision to undertake adaptation strategies depends on the perceived benefits of the different adaptation options, adaptive capacity of households, availability of options and the extent of variability. Finally, an adaptation option is considered effective as long as it can (at least partly) reduce the effects of variability and hence improve household income and food security.

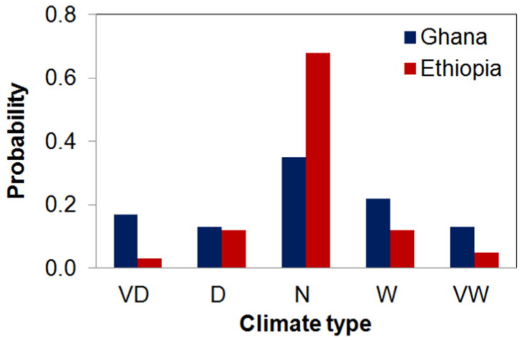

Fig. 3. Distribution of very dry (VD), dry (D), normal (N), wet (W) and very wet (VW) rainfall years in Ethiopia and Ghana.

3. Data sources and methods

3.1. Data

The data for this study are obtained from several sources. The Ethiopian Rural Household Survey (ERHS, 2011) that captures the different farming and agro-ecological conditions serves as the main data source for Ethiopia. In addition, we compiled plot and crop-level input and production data from the Nile basin data set for parametrizing yield response functions. To capture climate variability, historical rainfall records over the last 30 years (1980–2010) were obtained from the National Meteorology Agency (NMA). Using the time series climate data, we grouped each individual year into categories - normal (N), dry (D), wet (W), very dry (VD), and very wet (VW) - using the Standardized Anomaly Index (SAI).[2]

For Ghana, we obtained data from the 2005/2006 Ghana Living Standard Survey (GLSS5, 2008) and from the CGIAR Challenge Program on Water and Food (CPWF). The GLSS5 data set, a nationally representative survey of 8687 households, was used to estimate household consumption patterns. Data on disaggregated monthly regional prices, as well as daily precipitation and temperature were obtained from the CPWF

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[2] Normal (N): $-0.5 < \text{SAI} < 0.5$; Very Dry (VD): $\text{SAI} \leq -1.0$; Dry (D): $-1.0 < \text{SAI} < -0.5$; Wet (W): $1.0 < \text{SAI} < 0.5$; Very Wet (VW): $\text{SAI} \geq 1.0$.

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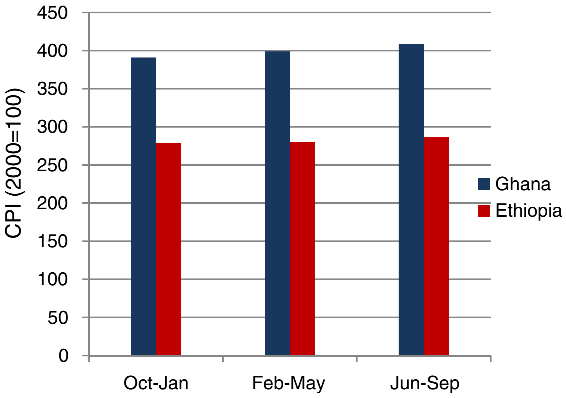

Fig. 4. Changes in consumer price index (CPI) by season, 2000 compared to 2014, Ghana and Ethiopia.

(1989–2009). Crop and plot level data were also obtained from CPWF to parameterize a Cobb-Douglas production function for yield response. Resource endowments such as land and livestock as well as household characteristics were also derived from the CPWF data source. The distribution of the different climate years for Ethiopia and Ghana along with their probability of occurrence shows that both countries have experienced extreme climate shocks (Fig. 3).

The 2000–2014 historical CPIs of Ethiopia and Ghana are obtained from the respective countries' statistical agencies and exhibit interesting seasonality as a reflection of their agricultural seasons (Fig. 4). Because the two countries have similar planting and harvesting seasons for major staple crops, we provide our estimates of the CPI and its variability for three intra-marketing-year seasons. The marketing year in both countries begins with the harvesting season (October to January), followed by the intermediate period (February to May), and the lean season (June to September). Food and non-alcoholic beverages contribute up to 60% of the CPI in Ethiopia and up to 45% in Ghana. The average CPI (2000 = 100) in Ethiopia increases by above 1 point between the harvesting and the intermediate seasons and by 7 points between the intermediate and the lean seasons (Fig. 4). The corresponding increases are higher for Ghana (above 8 and 18 points, respectively). This illustrates the importance of domestic production and seasonality in agricultural commodity prices for household welfare.

The CPI exhibits the largest variability during the lean season and the smallest during the harvesting season in Ethiopia, but vice versa in Ghana (Fig. 5).

Coefficients of variation of the CPI for the three seasons are averaged over all years (Fig. 5) and annualized (averaged over the respective three years; Fig. 6). However, what is true in both countries is that the volatility of the CPI was higher in 2012–2014 than in 2000–2002. Variability more than quadrupled in Ethiopia and nearly doubled in Ghana when the averages of the three-year periods before and after 2005 are compared.

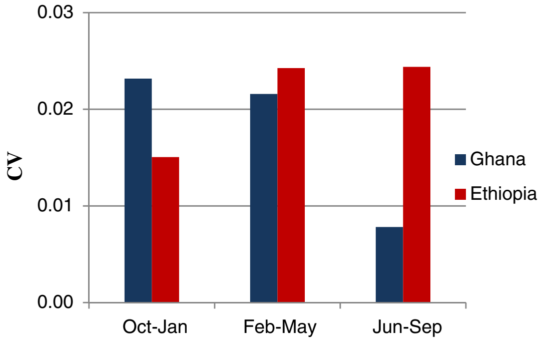

Fig. 5. Changes in the coefficient of variation of CPI by season, 2000 compared to 2014, Ghana and Ethiopia.

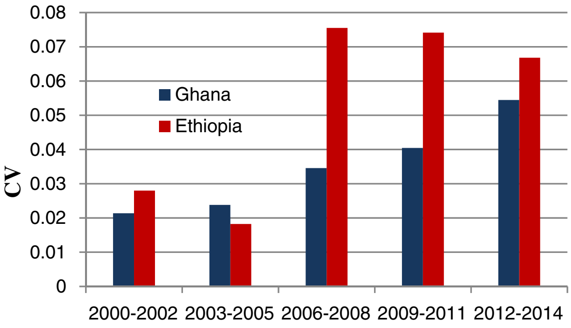

Fig. 6. Changes in the coefficient of variation of CPI, three-year periods, 2000 to 2014, Ghana and Ethiopia.

3.2. The agent based model

In this paper, we employ the agent-based software package MPMAS that captures farm-level impacts of climate and price variability and a wide range of adaptation options (Berger, 2001; Schreinemachers and Berger, 2011; Berger and Troost, 2014; Wossen et al., 2014; Troost and Berger, 2015; Wossen and Berger, 2015). MPMAS uses a whole-farm mathematical programming approach to simulate farmer decision-making in agricultural systems (Schreinemachers and Berger, 2011). Model equations and software architecture of MPMAS have been described in Schreinemachers and Berger (2011) following the ODD-protocol and are therefore not repeated in this paper. In the model, agents maximize expected income by choosing the optimal combination of crop, livestock, and non-farm activities subject to production and consumption preferences as well as resource endowments (such as labor, capital, land, and water).

At the beginning of the planting period, the model captures farmer investment decisions such as the growing of perennial crops, keeping of livestock, and production decisions, e.g., allocation of land for annual crops (Table 1). All production decisions are made based on actual resource supply and expected yields and prices.

The distribution of expected yield under different weather realizations was estimated using the Decision Support System for Agrotechnology Transfer (DSSAT) for Ethiopia (Jones et al., 2003; Hoogenboom et al., 2010) and the FAO crop growth model for Ghana. Since all production decisions are made based on expected yields and prices, climate and price variability can reduce income due to yield and price prediction errors. These climate-induced yield changes are then translated into consumption vulnerability using a parameterized demand system in a three-stage budgeting process (Schreinemachers and Berger, 2011; Wossen et al., 2014; Wossen and Berger, 2015). The budgeting process allocates income into savings and expenditure in the first stage. It then allocates total expenditure into food and non-food expenditure in the second stage and, in the final stage, food expenditure is allocated into specific food items using a parameterized demands system called Almost Ideal Demand System (AIDS). If unexpected food shortages occur as a result of prediction errors induced

Table 1
Summary of household decision making in MPMAS.

	Stage		
Characteristic	Investment	Production	Consumption
Timing	Start of the period	Start of the period	End of the period
Yields	Expected	Expected	Actual
Prices	Expected	Expected	Actual
Resource supply	Expected	Expected	Actual

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Table 2
Experimental design for ABM simulation analyses.

Scenario	Scenario type	Ethiopia	Ghana	Effects
a. No variability	Counterfactual scenario	1. Constant price and climate		
b. Variability + no adaptation	Baseline scenario	1. Variable price and climate		(b-a)/a
c. Variability + adaptation	Adaptation scenario	1. Access to credit	1. Access to credit	(c-b)/b
		2. Access to improved seed	2. Access to off-farm work	
		3. Fertilizer subsidy	3. Access to credit + off-farm work	
		4. All together		

by climate and price variability, households have to adopt ex-post through coping measures.

Owing to its agent-based nature, the model captures the characteristics of each household, its demographic composition, land rights, ownerships of durable assets and locations within agro-ecological zones and administrative units based on observed data. As a result, the model is able to reflect the complex inter-linkages among different production options, farm resources, and farmer characteristics (Schreinemachers and Berger, 2011; Wossen and Berger, 2015; Troost and Berger, 2015; Berger and Troost, 2014). In addition, the applied agent-based model captures agent-to-agent interactions and thus, in our setting, captures relations among agents for sharing resources and information for the adoption of adaptation strategies. Since the adoption of risk-reducing adaptation strategies against the adverse impacts of climate variability requires agent-to-agent interactions in which heterogeneity among agents and social relationships plays a significant role, the use of MPMAS is ideal (Berger and Troost, 2014).

3.3. Experimental design

Given our objective of examining the vulnerability of households to climate and price variability (i.e., “the effect of climate and price variability on household welfare with and without variability”), an experimental design in the spirit of counterfactual analysis is employed. A similar counterfactual analysis is also employed for examining the effectiveness of adaptation strategies (i.e., the welfare impact of adaptation strategies of households with and without adaptation (Di Falco et al., 2011)). As shown in Table 2, we construct a hypothetical baseline situation without any climate and price variability based on the long-term expected average climate and price as a counterfactual scenario (scenario **a**). For estimating the impact of climate variability, we exposed households to variability based on year-to-year variation of weather as obtained from NMA for Ethiopia and CPWF for Ghana (i.e., for each simulation run, a sequence of specific years was randomly drawn from the climate distribution and effects were simulated using MPMAS). Similarly, for estimating the effect of price variability, we exposed farm households to year-to-year price variations based on historical price data for both countries.

While estimating climate and price variability, we considered their joint distribution and ran a correlation analysis between observed rainfall and price for both Ethiopia and Ghana to determine the level of covariation between price and climate. We found a substantial co-variation in price and rainfall (with a statistically significant negative correlation) and considered this co-variation instead of randomly varying price and climate independently. Running the simulation with climate and price variability but without any form of policy intervention enabled us to estimate the “*baseline*” impact of climate and price variability (scenario **b**). By running the simulation with climate and price variability along with specific policy interventions and adaptation strategies, we were able to evaluate the effectiveness of adaptation options (scenario **c**).

The specific planned adaptation (policy intervention) strategies considered in the scenario analysis were innovation diffusion (mainly improved maize and wheat varieties), access to credit, fertilizer subsidy (only in Ethiopia), and improved access to off-farm employment. One possible intervention in response to food insecurity is the introduction of new technologies which increases agricultural productivity. The other policy intervention considered in the scenario analysis is related to improved access to short-term production credit. In the baseline, MPMAS was parameterized considering the current level of credit access (both from formal and informal sources of credit). As a policy intervention, we provide access to credit (from formal sources) for all agents using interest rates of current microfinance programs. We allow credit only for production purpose with strict rules for repayment and the use of credit for consumption purpose is not allowed. Finally, since adoption of high yielding improved varieties requires higher rates of fertilizer application, we considered fertilizer subsidies as another type of policy intervention. As no current fertilizer subsidy program exists in Ethiopia, a 25% fertilizer subsidy was implemented.

3.4. Model validation

Having parameterized the agent-based decision model, it was necessary to evaluate model results against real-world observations. In this paper, we compared simulated rates of food consumption and poverty incidence against real-world observations using baseline data on food consumption and poverty rates in Ethiopia and Ghana.

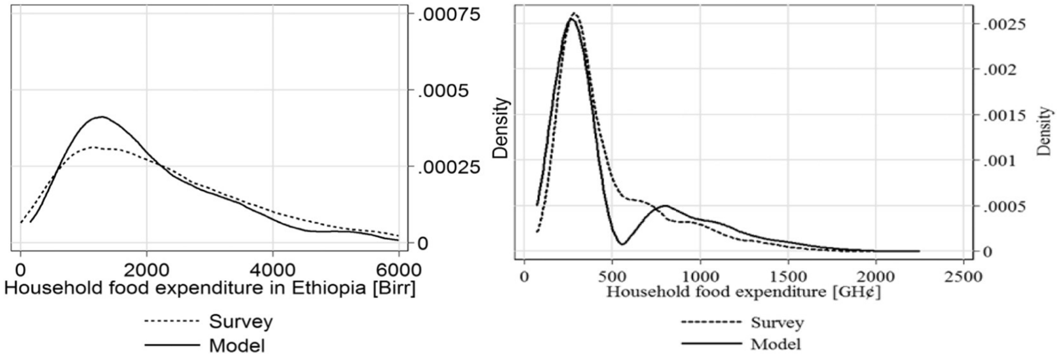

Fig. 7. Comparison of simulated and observed food expenditure distributions for Ethiopia and Ghana

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Table 3
Comparison of simulated and observed head count ratios, Ethiopia and Ghana.

Country	Ethiopia	Ghana
Simulated head count ratio (%)	39	69
Survey head count ratio (%)	35	70

3.4.1. Household food expenditure

Since household food expenditure is a key indicator of food security, validation of this indicator deserves high priority. Fig. 7 shows the simulated and observed distribution of household food expenditures in Ethiopia and Ghana. In both cases, there was a very high goodness of fit between observed and simulated food expenditures.

3.4.2. Poverty rates

As the second key policy indicator for model validation, we used head count poverty rates. Table 3 presents simulated and observed head count poverty rates and shows that distributions are very close for both countries.

4. Simulation results

This section presents the results of our simulation analysis on the impact of climate and price variability on income and food security. We first present the simulation results that address our first research question—that is, what is the expected average and distributional impacts of climate and price variability on household income and food security? We then present the results on the effectiveness of the different adaptation strategies, including their potential distributional effects.

4.1. Expected average and distributional impacts of climate and price variability on household income

The simulation results show that households in both regions are unable to buffer the effects of climate and price variability on their own (impacts were negative in both countries). As a result of climate and price variability, average agent income declined by about 5% in Ethiopia and 20% in Ghana. (Note that we used the terms households and agents interchangeably.) To design "*best-fit*" interventions instead of a *"one size fits all"* approach, it is important to capture the distributional aspect of the above reported impacts at the agent level. Results of our simulation on the impacts of climate and price variability across the different households in Ethiopia and Ghana underline this point. We ranked individual agents by their counterfactual income (without climate and price variability) and computed the change in household income compared with the baseline scenario (with observed climate and price variability; Fig. 8).

Table 4
Simulated percentage changes in household-level full income due climate and price variability, Ethiopia and Ghana.

Country	Ethiopia (%)	Ghana (%)
Mean effects of price and climate variability	−5	−20
Median effects of price and climate variability	−3.6	−21
Effect on the lowest decile	−11.9	−37.9
Effect on the highest decile	7.2	−2.8

A key result is that the impacts are largely negative for most agents. However, poor agents tend to be more vulnerable in both countries (Table 4). In principle, exposure to variability should, ceteris paribus, have the same effect irrespective of income levels. However, due to differences in initial endowments, climate and price variability will have differential effects on the poor and rich agents through the endowment effect. Since the impact of climate and price variability is not uniform, it may change the relative status of households within the community (Thiede, 2014). Such heterogeneous impacts could further exacerbate the existing inequality between the poor and rich agents.

The impact on the lowest deciles of agents is significantly larger than on those in the highest deciles along the income distribution for both Ethiopia and Ghana. A higher impact in the lowest deciles suggests that climate and price variability will exacerbate existing poverty. In fact, for Ethiopia, agents in the highest decile can significantly benefit and such heterogeneous effects on the poor and the rich may further increase inequality, conflict, and the incidence of poverty and food insecurity.

4.2. Potential distributional impacts of different coping and adaptation strategies on household income and food security

4.2.1. Impacts of coping options

It has been well documented that households implement different ex-post coping measures to smooth consumption against climate and price variability. The dominant means of coping against such adverse events include dissaving, selling assets (such as livestock), purchasing additional food, consuming less expensive or inferior food, and holding distress sales of eucalyptus. In addition, borrowing from social networks, receiving support from social ties and local institutions, and adjusting labor supply have also been mentioned as important coping option (Debebe et al., 2013; Wossen et al., 2015; Wossen et al., 2016). Herein, we focus on the role of livestock as a major mechanism of smoothing consumption against climate and price variability (Dercon and Christiaensen, 2011; Islam and Maitra, 2012; Debebe et al., 2013).

In particular, we examine how heterogeneity in livestock asset endowments may affect farm households' ability to cope shocks ex-post. Our analysis suggests that the impact of climate and price variability on consumption is considerable but smaller for those agents with

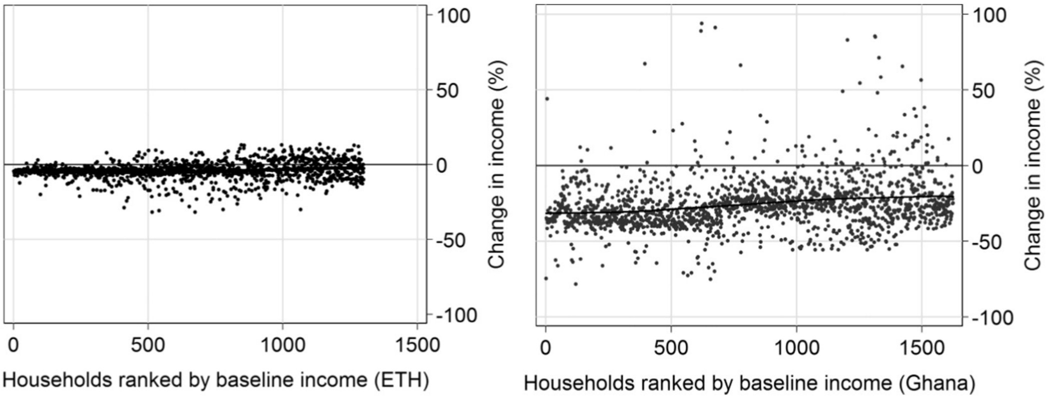

Fig. 8. Simulated distribution of change in household-level full income due to climate and price variability, by baseline income, Ethiopia and Ghana.

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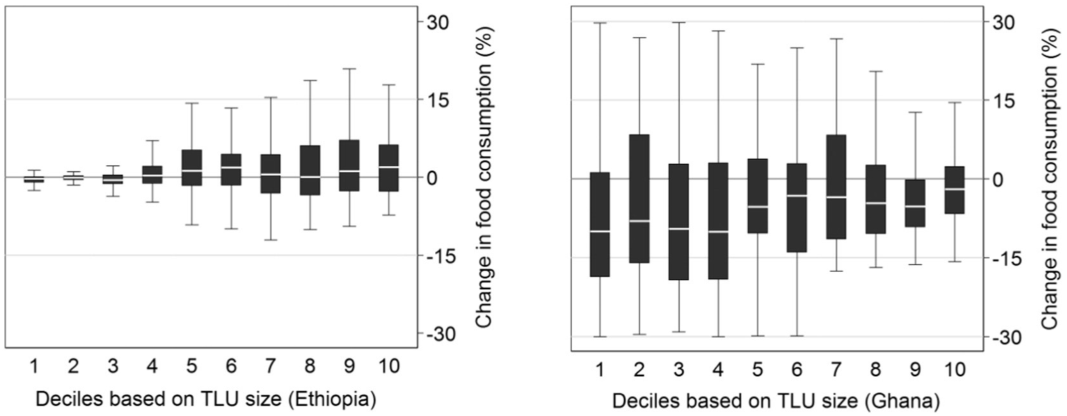

Fig. 9. Simulated means and distributions of changes in food consumption with climate and price variability, by TLU decile, Ethiopia and Ghana.

Table 5
Summary of mean impacts on household-level full income for simulation scenarios including adaptation options.

Indicator	Case study	Without variability	With climate and price variability	Credit	Credit plus fertilizer subsidy	Credit plus off-farm	Credit plus fertilizer subsidy plus adoption of improved crop varieties
Change in average income (%)	Ethiopia	n/a	−5	0.88	3	n/a	4.2
	Ghana	n/a	−21.5	17	n/a	29.3	n/a
Food insecurity (%)	Ethiopia	35.3	36.5	36.3	36	n/a	35.9
	Ghana	60.8	69.7	37.5	n/a	24.7	n/a
Share of winners (%)	Ethiopia	n/a	16.5	74.4	88	n/a	87
	Ghana	n/a	8.3	77.3	n/a	88.9	n/a

relatively larger livestock endowments in both countries (Fig. 9). This finding is consistent with the hypothesis that households use livestock wealth to smooth consumption under climate and price variability.

4.2.2. Impacts of adaptation options

Next, we also consider the effectiveness of adaptation options under climate and price variability. Table 5 summarizes the simulation results on the distributional aspects of policy interventions considering the following key policy indicators: (i) income, that is, average change of income compared with the counterfactual without any variability; (ii) food security—the share of agents that failed to meet the minimum food consumption expenditure; and (iii) heterogeneity of impact, measured as the share of agents who are able to maintain or increase their income as compared with the counterfactual without any variability.

As shown in Table 5, only 16.5% of the agents in Ethiopia and 8.3% in Ghana were able to maintain or increase their income under climate and price variability compared with the counterfactual situation of no climate and price variability. With policy interventions such as credit, off-farm activities, and adoption of improved crop varieties, the share of winners increased significantly. For instance, with access to credit about 74.4% of agents in Ethiopia and 77.3% in Ghana can increase their incomes. The results presented in the last row of Table 5 suggest that policy interventions not only improve the level of income and food security of farm households but also benefit a significant number as the share of winners is large for all policy interventions.

The patterns in Fig. 10 indicate that adaptation options did not completely offset the impacts of climate and price variability for poor farm households.[3] The distribution suggests that policy interventions were more pro-poor in Ghana than in Ethiopia.

5. Discussion

The simulation results in section 4 suggest that climate and price variability adversely affects household income and food security, whereas self-coping mechanisms through livestock sales are not sufficient to shield most households from the impacts of climate and price variability. Adaptation options supported by policy interventions (often packages of them) are likely to be necessary for full mitigation of negative impacts on income. Herein we discuss the above main results.

5.1. Impacts of climate and price variability

Our simulation results suggest that climate and price variability affects household income and food security adversely in Ethiopia and Ghana, but understanding the wider implications of such effects requires examining the pathways through which food security and income may be affected. In these settings, climate and price variability affects income (and perhaps food security) primarily through productivity pathways. In particular, as a result of climate and price variability, farmers alter their input allocation, crop choice and consumption preference. As such, policy interventions geared towards improving farmers' access to output and input markets through prudent management of price variability are crucial. In addition, price stabilization policies, such as reducing price margins, could be important to improve the earning capacity of farm households. Moreover, given that climate and price variability reduces the uptake of technology, due emphasis must be given to the management of down-side risk. For example, due to consumption requirements, households may produce crops with low mean and low variance, leading to poverty traps. Our simulation experiment shows that farm households significantly reduced the use of chemical fertilizer as a result of climate and price variability. When examining the factors responsible for variation across different agents, we found that agents who are adversely affected were characterized by low application rates of fertilizer, limited livestock endowments, and a smaller farm size.

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[3] The results are based on the scenario where all the policy combinations were provided simultaneously. Credit plus fertilizer subsidy plus adoption of improved crop varieties for Ethiopia and credit plus off-farm plus irrigation for Ghana.

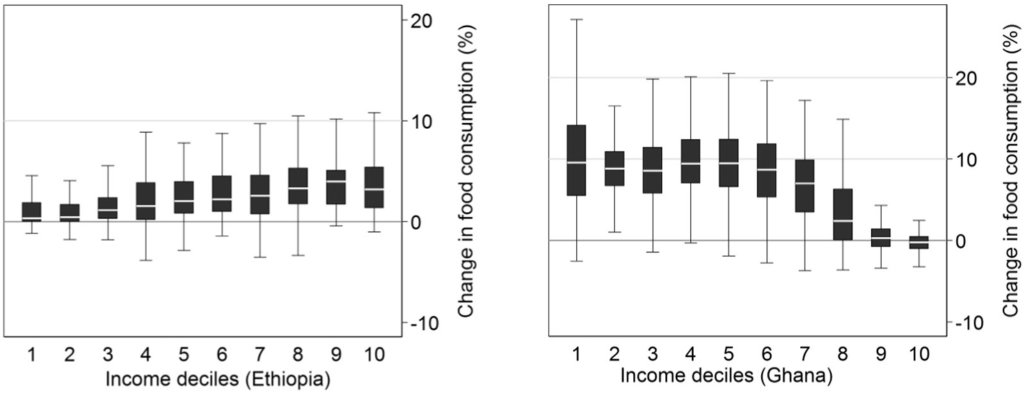

Fig. 10. Simulated means and distributions of changes in household-level full incomes with adaptation options, by income decile, Ethiopia and Ghana.

5.2. Effectiveness of coping options

Our simulation results indicated that the effects of climate and price variability on consumption are considerable, but are smaller for those households with relatively large livestock endowments in Ethiopia and Ghana. However, self-coping strategies were not sufficient to mitigate the impacts of climate and price variability. Therefore, policy interventions designed to improve the asset-base of farm households may be necessary. In addition, provision of other ex-post coping mechanisms is important to avoid households engaging in coping mechanisms that erode their assets. For instance, our simulation results suggest that dis-investment options through livestock sales would help farmers to cope with the impacts of climate and price variability. However, coping through the sale of livestock may lead to long-term asset poverty traps (Wossen et al., 2016; Stephens et al., 2012). In addition, well-targeted consumption credits, such as food for work and other production-oriented safety nets, might be important in reducing the impacts of variability while improving productivity.

5.3. Effectiveness of adaptation options

Our simulation results also indicated significant differences in income and food security levels between those farm households that implemented adaptation options and those that did not. For Ethiopia strategies composed of a portfolio of actions (such as credit and fertilizer subsidies alongside new technologies) could be effective in reducing the impacts of climate and price variability. In Ghana, policy interventions aimed at improving the provision of short-term production credit along with the current irrigation facilities were found to improve household-level full income (and perhaps food security). Single interventions such as credit or irrigation, were not as effective as multi-faceted ones in maintaining household incomes. Thus, it appears there is a need for a mix of interventions to be available to households if the adverse effects of climate and price variability are to be reduced. However, the costs and benefits of implementing multiple adaptation options need to be more fully assessed and when deemed appropriate, policy makers may also be required to improve institutional capabilities to ensure access to lower-income farm households. For example, creating an agricultural information system supported by mobile or radio technology in a manner that is understandable and useful for farmers would be a good policy intervention.

It is worth noting that not all adaptation practices through policy interventions reduce variability but they can reduce vulnerability if appropriately targeted. This leads to the question of what constitutes a successful adaptation. We believe that successful policy interventions aimed at increasing adaptive capacity should improve the livelihoods of the poor. Adaption can improve mean incomes but at the same time result in increased income inequality if positive effects are accrued to better-off households with higher assets or incomes. More successful adaptation strategies should attempt to improve incomes without exacerbating inequality. Given that both climate and price variability have an adverse effect, policy interventions that yield pay-offs in the short-run may be appropriate. These could include policy interventions to improve the use of technologies currently available, (e.g., irrigation and improved seed varieties), inputs (such as fertilizer and related credit provision) and off-farm income-generating opportunities.

6. Conclusion

Our study applied MPMAS to address the challenges of climate and price variability in the context of small-scale and “semi-subsistence agriculture” while capturing non-separable production and consumption decisions as well as the role of coping mechanisms for consumption smoothing. The main findings can be summarized as follows: Farm households in both countries are vulnerable to climate and price variability, and the effects are not uniform across the income distribution of the agent population. “Self-coping” strategies (such as livestock sales) had a positive short-run impact, but were not sufficient to fully mitigate the impacts of climate and price variability. Thus, policy interventions may be necessary to allow households to mitigate fully the negative impacts of variability on income. In Ethiopia, a portfolio of interventions composed of access to credit, fertilizer subsidies and new technologies were more effective at limiting negative impacts on income. However, to be effective, it is likely that changes to institutional capacity would be required to more fully develop and implement these interventions, and to ensure their availability to farms throughout the income distribution. Our results also highlight the importance of a mix of policy interventions to appropriately respond to the adverse effects of climate and price variability in Ghana. Policy interventions aimed at improving the provision of short-term production credit along with existing irrigation facilities were found to be particularly important in Ghana. Due to the lack of adequate empirical data, we modelled only the most important individual agent-coping strategies of smallholders without explicitly considering the role of local safety nets and kinship ties. Nevertheless, the results indicate that targeting policy interventions and adaptation options based on average effects might increase inequality between the poor and the rich.

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Please cite this article as: Wossen, T., et al., Impacts of climate variability and food price volatility on household income and food security of farm households in East and West..., Agricultural Systems (2017), http://dx.doi.org/10.1016/j.agsy.2017.02.006

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